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WAVE PROPAGATION IN DENSE GEOPHYSICAL MEDIA(U)
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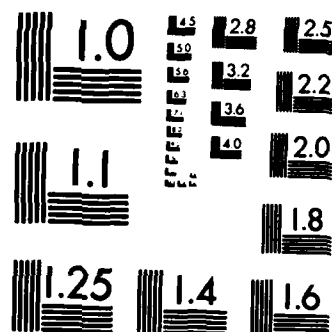
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This final report summarizes our study of the interactions between the wave characteristics and the dense geophysical media. We have clarified the propagation constant of the coherent wave in a dense medium, conducted a pulse-broadening study, observed an interesting backscattering phenomenon, and investigated vector radiative transfer theory.		

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WAVE PROPAGATION IN DENSE GEOPHYSICAL MEDIA

FINAL REPORT

Akira Ishimaru

June 12, 1984

U.S. ARMY RESEARCH OFFICE

Contract DAAG 29-81-K-0065

University of Washington

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A. STATEMENT OF THE PROBLEM STUDIED

Theoretical and experimental studies have been conducted to clarify the interrelations between the wave characteristics and the dense geophysical scattering medium. Experimental studies have involved carefully controlled optical and ultrasound measurements. This basic information will be used to obtain useful numerical codes for the wave characteristics in the actual atmospheric and terrestrial environments.

B. SUMMARY OF THE MOST IMPORTANT RESULTS

The propagation constant of the coherent field in a dense scattering medium has been studied experimentally with controlled optical measurements. At a density higher than 1%, the attenuation constants show a marked departure from the low density Foldy approximation. This departure has been measured for different particle sizes and compared with theoretical predictions which include pair-correlations of scatterers. We have not, however, completed the study of the phase constant.

We have conducted pulse broadening experiments using pico-second optical pulse. We obtained some practical results, but our studies are still not complete, and we intend to continue this work using ultrasound.

We observed an interesting phenomenon showing a sharp peak in the backscattering direction with the small angular width corresponding to the lateral correlation distance of a mean free path. We have confirmed this experimentally and theoretically using the second-order multiple scattering theory.

We have also investigated the vector radiative transfer theory for nonspherical scatterers. It indicates two propagation constants for the

coherent field, and the radiative transfer equation includes a 4×4 extinction matrix. Further study on this and beam wave problems is continuing.

C. LIST OF MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER ARO SPONSORSHIP
DURING THIS PERIOD

"Attenuation constant of coherent field in a dense distribution of particles," Journal of the Optical Society of America, 72:10, pp. 1317-1320, October 1982; coauthor, Y. Kuga.

"Transmission, backscattering, and depolarization of waves in randomly distributed spherical particles," Applied Optics, 21:20, pp. 3792-3798, October 1982; coauthor, R. Cheung.

"Scattering and diffusion of a beam wave in randomly distributed scatterers," Journal of the Optical Society of America, 73:2, pp. 131-136, February 1983; coauthors, Y. Kuga, R. Cheung, and K. Shimizu.

"Multiple scattering theory for waves in discrete random media and comparison with experiments," Radio Science, 18:3, pp. 321-327, May-June 1983; coauthors, V. K. Varadan, V. N. Bringi, and V. V. Varadan.

"Acoustic wave propagation in randomly distributed spherical particles," Journal of the Acoustical Society of America, 74:5, pp. 1529-1534, November 1983; coauthors, J. C. Machado and R. A. Sigelmann.

"Experiments on picosecond pulse propagation in a diffuse medium," Journal of the Optical Society of America, 73:12, pp. 1812-1815, December 1983; coauthors, Y. Kuga and A. P. Bruckner.

"Matrix representations of the vector radiative-transfer theory for randomly distributed nonspherical particles," Journal of the Optical Society of America A, 1:4, pp. 359-364, April 1984; coauthor, C. W. Yeh.

"Backscattering enhancement of random discrete scatterers," accepted Journal of the Optical Society of America; coauthor; L. Tsang.

"Retroreflectance from a dense distribution of spherical particles," accepted Journal of the Optical Society of America; coauthor; Y. Kuga.

"On the difference between Ishimaru's and Furutsu's theories on pulse propagation in discrete random media," Journal of the Optical Society of America A, 1:5, pp. 506-509, May 1984.

C. PRESENTATIONS AT MEETINGS

A. Ishimaru, "Multiple scattering effects on optical propagation in turbulence and particles," NATO-AGARD Meeting, Monterey, California, April 1981.

Y. Kuga and A. Ishimaru, "Attenuation constant of coherent field in dense spherical particles," National Radio Science Meeting, Los Angeles, June 1981.

R. L.-T. Cheung and A. Ishimaru, "Transmission and backscattering of optical waves through fog," National Radio Science Meeting, Los Angeles, June 1981.

A. Ishimaru, R. A. Sigelmann, K.-L. Peng, and R. Campbell, "A theoretical and experimental study on statistical EMI," IEEE Symposium on Electromagnetic Compatibility, Boulder, August 1981.

A. Ishimaru, "Multiple scattering in turbulence, scatterers, and rough surfaces," URSI Symposium on Mathematical Models of Radio Propagation, Washington, DC, August 1981.

A. Ishimaru and R. L.-T. Cheung, "Transmission, backscattering, and depolarization of waves in randomly distributed spherical particles," National Radio Science Meeting, Albuquerque, May 1982.

A. Ishimaru, "Frequency spectra of ultrasound pulses reflected from scattering medium," 7th International Symposium on Ultrasonic Imaging and Tissue Characterization, NBS, Gaithersburg, Maryland, June 1982.

J. Machado, R. A. Sigelmann, and A. Ishimaru, "Experimental and theoretical study of phase and amplitude of ultrasonic waves through random medium," 7th International Symposium on Ultrasonic Imaging and Tissue Characterization, NBS, Gaithersburg, Maryland, June 1982.

A. Ishimaru, "Introduction to the theory and application of wave propagation and scattering in random media," SPIE (International Society for Optical Engineering) Meeting on Applications of Mathematics in Modern Optics, San Diego, August 1982.

R. Woo, D. C. Blackman, and A. Ishimaru, "First-order calculations of incoherent intensity due to rain," National Radio Science Meeting, Boulder, January 1983.

A. Ishimaru and C. Yeh, "Radiative Transfer Theory for Randomly Distributed Nonspherical Particles," National Radio Science Meeting, Houston, May 1983.

C. PRESENTATIONS AT MEETINGS (Continued)

A. Ishimaru, "Scattering of Electromagnetic Waves in a Random Distribution of Nonspherical Particles," International URSI Symposium on Electromagnetic Theory, Santiago de Compostela, Spain, August 1983.

A. Ishimaru, "The radiative transfer approach in electromagnetic imaging," NATO Advanced Research Workshop on "Inverse Methods in Electromagnetic Imaging," Bad Windsheim, Federal Republic of Germany, September 1983.

A. Ishimaru, "Vector multiple scattering theory for nonspherical particles," OSA Meeting, New Orleans, October 1983.

J. C. Machado, R. A. Sigelmann, and A. Ishimaru, "Ultrasound and propagation in randomly distributed particles," ASA Meeting, San Diego, November 1983.

D. R. Jackson, D. P. Winebrenner, and A. Ishimaru, "Application of the composite roughness model to bottom backscattering," ASA Meeting, San Diego, November 1983.

Y. Kuga and A. Ishimaru, "Retroreflectance from a dense distribution of spherical particles," National Radio Science Meeting, Boulder, Colorado, January 1984.

D. Winebrenner and A. Ishimaru, "Rough surface scattering based on the extinction theorem," National Radio Science Meeting, Boulder, Colorado, January 1984.

A. Ishimaru, "Some current and outstanding problems for waves in random discrete scatterers," National Radio Science Meeting, Boulder, Colorado, January 1984.

D. Winebrenner and A. Ishimaru, "Perturbation theory for scattering from random rough surfaces using the extended boundary condition," ASA Meeting, Norfolk, Virginia, May 1984.

A. Ishimaru, D. Lesselier, and C. Yeh, "Application of the radiative transfer theory to the multiple scattering by low- and high-loss nonspherical particles," IEEE/AP-S Symposium and National Radio Science Meeting, Boston, Massachusetts, June 1984.

A. Ishimaru, "Diffusion approximation of time-dependent transport equation," SIAM Meeting, Seattle, Washington, July 1984.

C. PRESENTATIONS AT MEETINGS (Continued)

R. L.-T. Cheung, "Millimeter and optical waves in rain and fog," Ph.D. Dissertation, Electrical Engineering Department, University of Washington, December 1981.

Y. Kuga, "Experimental and theoretical studies of the laser light propagation and scattering in a dense distribution of spherical particles," Ph.D. Dissertation, Electrical Engineering Department, University of Washington, July 1983.

J. C. Machado, "Experimental and theoretical investigations of propagation and scattering of ultrasound in randomly distributed spherical particles," Ph.D. Dissertation, Electrical Engineering Department, University of Washington, July 1983.

D. PARTICIPATING SCIENTIFIC PERSONNEL

Akira Ishimaru, Principal Investigator

Rubens A. Sigelmann, Investigator

R. L.-T. Cheung, Ph.D. Awarded December 1981

Y. Kuga, Ph.D. Awarded August 1983,
Presently Research Assistant Professor

J. Machado, Ph.D. Awarded August 1983

H. W. Chang, Research Assistant